OBJECTIVES

- **A** Relate changes in climate to Earth's energy budget.
- **B** Identify some causes of global cooling and warming.
- **C** Explain the effects of greenhouse gases on global climate.
- **D** Discuss ways scientists are studying global climate changes.

IV Climate Change

Topic 14 Sources of Climate Change

The weather varies a lot from day to day and season to season. So it is hard to tell without averaging numbers whether the climate is changing. But what averages are most useful? Is Earth's climate getting warmer? Scientists are using the study of past climate changes to make predictions about future climate changes.

Earth's climate changes with its energy budget. Right now Earth's energy budget is in approximate balance (see Chapter 26, Topic 8). That is, the incoming solar radiation (insolation) is equal to the energy Earth loses to space. To see what can change the balance, one must look at the processes involved. First, solar radiation hits Earth and its atmosphere. Second, Earth loses energy by reflection of sunlight from its surface and from clouds, dust, and air molecules in the atmosphere. Third, Earth's surface, clouds, and atmosphere lose infrared radiation (heat) to space. And fourth, *greenhouse gases,* such as carbon dioxide, let sunlight in but keep infrared radiation from escaping to space. A change in any of these four processes can change the climate.

Do climate changes in Earth's past provide clues about future climate changes? Earth has had at least four ice ages in the last 3 million years. At other times, Earth became so warm that even Greenland and Antarctica had tropical climates. It appears that changes in Earth's heat budget need not be very large to trigger climate changes. For example, temperatures during the last Ice Age were only 5°C cooler than today's temperatures. Scientists from many disciplines—astronomy, geology, chemistry, oceanography, biology, and meteorology—have joined in the study of climate change. These scientists hope that, as they learn more about climate changes in Earth's past, they will be able to predict future changes in Earth's climate.

Topic 15 Causes of Global Cooling

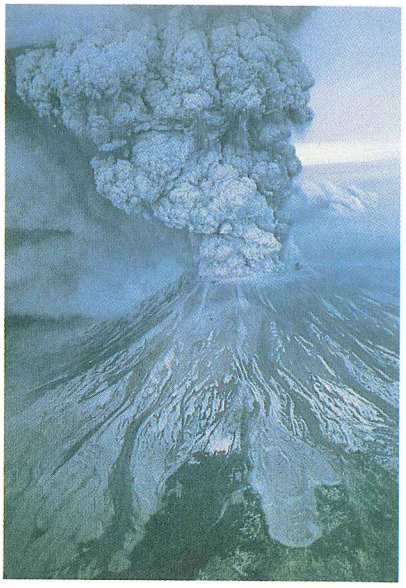
Cooling periods in Earth's history have been linked to variations in the sun's energy output. The less energy put out by the sun, the less energy there is available to reach Earth. There is strong evidence that solar energy output increases with an increase in the number of sunspots (Chapter 22, Topic 4). The opposite is also true. During a cold period on Earth, between the years 1400 and 1800, there were almost no sunspots. Scientists estimate that the amount of solar energy reaching Earth was down by 0.25 percent. Even such a small change in incoming energy has an impact on Earth's climate. Earth cooled so much during this "Little Ice Age" that valley glaciers advanced in Europe and North America.

There may be other ways to decrease the amount of solar energy reaching Earth's surface. Scientists think that changes in

Earth's orbit may cause some of the cooling. The shape of Earth's orbit sometimes puts Earth closer to the sun. This could change the amount of solar energy Earth receives. Climate may also be affected by the wobble of Earth on its axis.

Cooling would also occur if solar energy is prevented from reaching Earth's surface. Dust particles in the upper atmosphere can reflect the sun's energy back into space. These particles can come from volcanoes or rarely from the impact of asteroids. Explosive volcanic eruptions inject dust and sulfur dioxide gas into the stratosphere. The sulfur dioxide reacts with water vapor to form tiny droplets of acid. The dust and the acid droplets are so small that they can stay suspended for one to seven years. During this time, the dust and droplets reflect sunlight back into space. This reduces the amount of sunlight reaching Earth's surface which can cool the temperatures up to a few tenths of a degree Celsius. Once the dust falls into the troposphere, it is washed out by rain. The 1991 eruption of Mount Pinatubo in the Philippines, put 15 to 20 million tons of ash and sulfur dioxide into the stratosphere. A typical explosive eruption can lower mid-latitude temperatures between 0.1°C and 1°C.

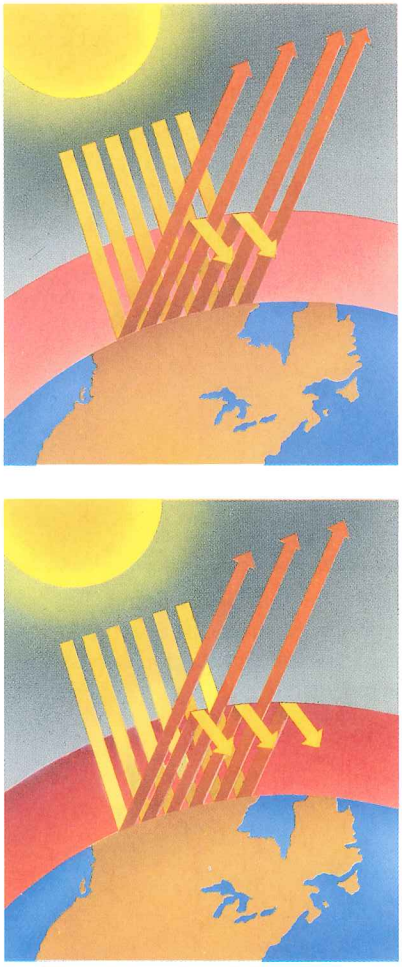
Finally Earth's climate can be cooled when heat normally circulated by Earth's atmosphere or ocean currents is changed. Plate tectonics shapes both local and global climate by changing the energy distribution in Earth's heat budget. The continents have not always been located where they are today (Chapters 13 and 34), nor have oceans always been the same shape and size. These changes in sizes and positions of oceans and continents affected wind patterns, ocean currents, and the amount of solar radiation reflected back into space from land and water. For example, today there are large land areas in the cold regions surrounding the North and South poles. In the past, those landmasses were in the middle of oceans where air and ocean currents allowed enough exchange of heat with the atmosphere to distribute temperatures more uniformly. When large landmasses are located near the poles, the heat difference between the poles and the equator increases. During glaciation, when more of the land is covered with snow and ice, a greater amount of sunlight is reflected back into space. This contributes to cooling.



31.8 An individual volcanic eruption, such as this eruption, may cool the atmosphere for two to seven years.

Topic 16 Causes of Global Warming

As you learned in Chapter 26, carbon dioxide plays a major role in keeping Earth's temperature constant. However, too much carbon dioxide causes a build-up of heat in Earth's atmosphere. The burning of fossil fuels, such as oil and coal, and the destruction of the world's rain forests are returning carbon dioxide to the atmosphere much faster than carbon dioxide can be removed by plants and by the oceans. Many scientists predict that an increase in carbon dioxide and other greenhouse gases (Chapter 26, Topic 9) can lead to global warming.

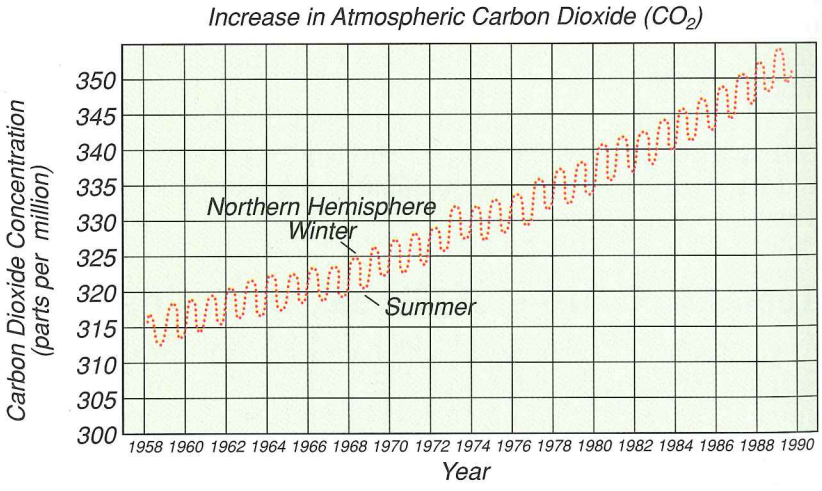


31.9 (Top) Carbon dioxide, water vapor and methane absorb radiation leaving Earth. (Bottom) As the concentration of these substances increases, more radiation is absorbed causing a global warming trend.

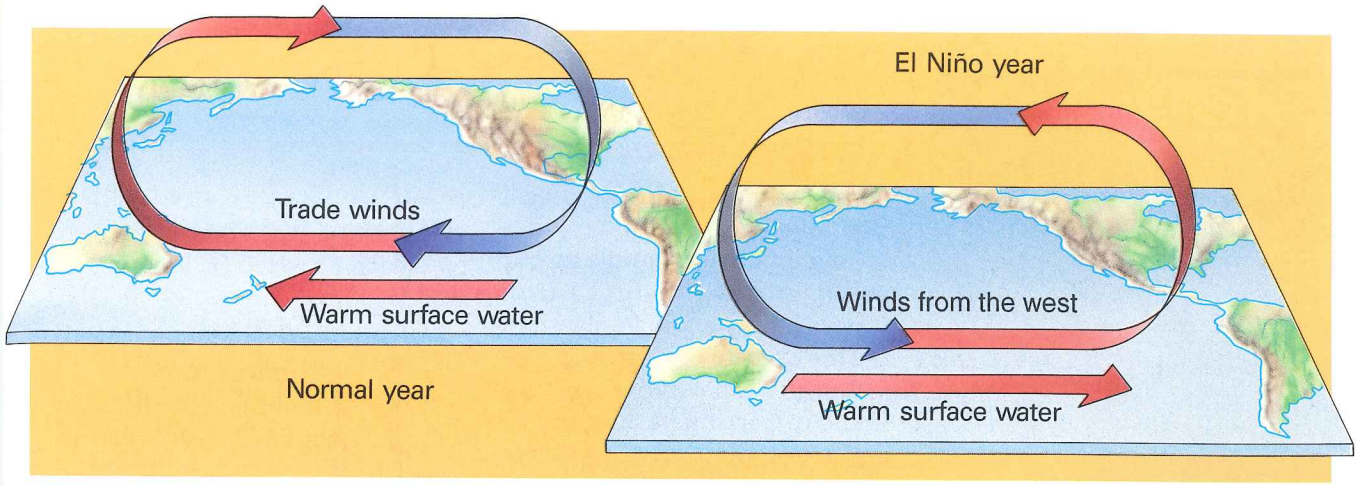
Volcanic eruptions also inject carbon dioxide into the atmosphere. This carbon dioxide stays in the atmosphere long after the volcanic dust and sulfuric acid droplets settle out. If there were many explosive volcanic eruptions over several million years, the increased amount of carbon dioxide could warm the climate. The relative warmth during the Cretaceous Period is thought to be related to volcanic activity.

If global warming did occur, some of today's most productive agricultural areas would become too dry or too hot to support the crops currently grown there. The polar ice caps and alpine glaciers could melt, causing sea level to rise and to flood coastal cities. However, such predictions are controversial and impossible to test.

Not all warming of Earth's climate is long-term. A natural event believed to cause short-term warming is called *El Niño*. Normally the warmest sea-surface temperatures on Earth occur in the western Pacific. Air pressure along the sea surface in that area, is low and the heaviest rains over Earth's oceans occur there. The trade winds blowing towards the west, strengthened by the overlying low pressure, keep warm water piled up in the western Pacific. Occasionally, the winds around the equator blow from the west, opposite the normal direction, as shown in Figure 31.11. During an El Niño event the west winds last long enough to spread the warm water eastward across the Pacific. This happens every two to eight years. El Niño events cause changes in Earth's climate. During a strong El Niño event, global surface temperatures warm by 0.1 to 0.2°C, which affects global weather patterns. Winters over Canada and the northern United States becomes milder, the southeast United States gets more precipitation, and fewer Atlantic hurricanes occur.



31.10 Concentration of carbon dioxide at Mauna Loa Observatory, Hawaii. Scientists believe that the data represents global trends. The seasonal variations are due to plants uptake of carbon dioxide.



31.11 El Niño, a warm surface current in the Pacific Ocean can cause short-term climate changes.

Topic 17 Is Climate Getting Warmer?

The severe heat and drought that peaked in the late 1980's have raised questions about Earth's climate and greenhouse gases. Six of the hottest ten years of the last century were in the 1980's. Scientists are sifting through old weather records and building computer models of climate to determine whether that warming is temporary or part of a long-term, global warming trend.

With so many factors influencing Earth's heat budget, it is difficult to make simple models of global climate change. The computer models being used to sort out the many causes of climate change are similar to those used for weather forecasting. The models are used to describe the present climate, its seasonal changes, and to predict the changes that might result from such things as volcanic eruptions or El Niño events. In addition, scientists test the models by trying to reproduce past climates using data pieced together from geologic evidence.

Unfortunately the factors affecting global climate change are numerous and complex. Climate models must take into account such factors as the effects of oceans, changes in greenhouse gases, the effects of different cloud types on sunlight at different altitudes, and so on. This makes predicting climate change difficult.

TOPIC QUESTIONS

Each topic question refers to the topic of the same number.

14. **(a)** What happens when Earth's energy budget changes? **(b)** List four ways in which Earth's energy budget can change.

15. **(a)** List four factors that might cause global cooling. **(b)** How do volcanic eruptions cause temperatures to lower?

16. **(a)** Explain how an increase in greenhouse gases produces warming at Earth's surface. **(b)** Describe what might happen if global warming did occur. **(c)** What is El Niño? How has El Niño affected weather in North America?

17. **(a)** Name two ways climate models are tested. **(b)** List three factors computer models must account for when predicting global climate change.